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UNMANNED AERIAL VEHICLES – REVOLUTIONARY TOOLS IN WAR AND PEACE

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ABSTRACT

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The unmanned aerial vehicle's (UAV) operational impact is growing as compared to manned weapon systems. Historical evolution of the UAV has been marked by a series of inconsistent periods of technological development followed by stagnation. It was not until Vietnam that the UAV had a measurable impact on military operations. However, following the technological progress spurred on by the Vietnam War, the UAV was again forsaken by military leadership. Tremendously successful employment of UAVs by the Israelis, combined with the changing nature of warfare, once again evoked interest from the United States in UAV development and employment. Finally, UAVs emerged from the shadow of manned aircraft in the mid-1990s, and became an integral weapon in the global war on terror.

This paper will examine the future doctrinal, organizational, and operational effects of the UAV across the Department of Defense. The examination will include: (1) an overview of the background and historical development of UAVs and the concept of the “revolution in military affairs”; (2) a review of current major DoD UAV systems and operational concepts; (3) an analysis of the strategic impact of UAV systems, assessing whether the UAV can be considered a revolutionary instrument for the military services.

UNMANNED AERIAL VEHICLES – REVOLUTIONARY TOOLS IN WAR AND PEACE

> All the business of war, and indeed all the business of life, is to endeavor to find out what you don't know by what you do know; that's what I called guessing what was on the other side of the hill.[1]
>
> —Duke of Wellington (1884)

In 1903, the Wright Brothers historic first sortie at Kitty Hawk, North Carolina, touched off a revolution in manned flight. Ironically, the first powered, sustained, controlled flight of an unmanned heavier-than-air vehicle was conducted seven years prior to the Wright Brothers. In 1896, Samuel P. Langley flew his unmanned aerial vehicle (UAV), named Aerodrome No. 5, over the Potomac River for a full minute.[2] However, rather than starting a revolution in UAV development, Langley's steam-powered vehicle instead was the first in a long line of innovative, imaginative craft that unfortunately remained subordinate to manned platforms. It was not until the wars in Iraq and Afghanistan, over 100 years after Langley's first unmanned flight, that the UAV finally overcame the manned aircraft institutional bias and became a key asset in the United States Air Force (USAF) inventory and a critical weapon in the global war on terror. The UAV has fulfilled the vision of the Duke of Wellington above, by enabling today's soldier to truly see what is "on the other side of the hill."

The history of the UAV as a weapon of war is marked by inconsistency. Short periods of tremendous investment, development and usually limited operational use of the UAV were followed by long periods of dormancy in UAV development. As will be seen, wartime need drove UAV development. However, since the tragic attacks of 9/11, and the global war on terror, the UAV has shown to be a critical asset on the battlefield and has frequently been described as "transformational." UAVs now perform a vast array of military and civilian missions throughout the world, including intelligence, surveillance and reconnaissance (ISR), close air support, interdiction, suppression of enemy air defenses, radio relay, observation, border security and maritime surveillance. Is the UAV a revolutionary new tool that will re-shape military planning and execution, or will the current explosion in UAV interest once again fade as it has in the past?

Before proceeding, it is important to define some terms. The Department of Defense (DoD) definition of the UAV is "a powered aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload."[3] Therefore, ballistic or semi ballistic missiles, cruise missiles, artillery projectiles, and unmanned balloons or airships

are not considered UAVs. The term remotely piloted vehicle (RPV) was in use until the mid-1980's, when "UAV" began to replace it, since RPVs are solely piloted remotely by a human. Some types of modern UAVs are fully autonomous, with no human real-time pilot, though the vast majority of current UAVs still require a human interface.

Soviet military theorists in the early 1970s identified two major periods of change in the military and conduct of warfare during the 20th century. The first, during the World War I era, was driven by the development of aircraft, motor vehicles, and chemical weapons. The second, during World War II, was defined by the development of missiles, computers, and nuclear weapons. This impact of technology on the conduct of warfare was termed a "military technological revolution." This term has been further refined, in recent decades, by modern military theorists as a "revolution in military affairs," or RMA. Further study of the concept of an RMA has led to military theorists defining as many as ten separate RMAs since the 14th century, starting with the Infantry RMA and the Artillery RMA during the Hundred Years War. Advances in naval technology, guns, fortress design, mechanization, aviation and information were also identified by some as RMAs. The Nuclear RMA, resulting from the marriage of nuclear weapons with modern delivery systems, was the generally-accepted last definable RMA.[4]

What defines an RMA? The concept includes three basic core elements. First, an RMA is usually driven by a technological breakthrough or radically new strategy. Second, this major change drives doctrinal and organizational changes. Finally, these changes fundamentally alter the entire conduct of military operations. So radical are these changes that the nature of warfare following the RMA is profoundly different.[5] Some modern military theorists assert that the rise of the precision-guided munition (PGM), used for the first time with effectiveness during the first Gulf War of 1991, was an RMA. Others view PGMs as part of a larger system-of-systems approach to the next RMA, along with the fusing of data from intelligence, surveillance and reconnaissance systems. This theory includes UAVs as an element of a larger Net-Centric Warfare RMA.[6] Are current UAVs truly transformational, or are they just another weapon system in the DoD arsenal? Before tackling this issue, it is important to look back at the history of UAV development, to see what led to current UAV design and what may influence the future of UAVs.

From the Ancient Era to the 1920s

Over two thousand years ago, a lone Chinese man stood on a hill and completed history's first UAV sortie -- he flew a kite, with the string as the "downlink to the pilot."[7] The first military

use of kites was in the second century B.C. when a Chinese general used them to estimate the distance for a tunnel being dug under his enemy's fortifications.[8] European military use of kites was first noted at the Battle of Hastings in 1066, where they were used for communication (signaling).[9] Thus the first military use of the UAV was for reconnaissance and communication, missions that UAVs even today perform superbly.

In the United States, UAVs developed in parallel with an increasingly professionalized, technologically advanced, permanent military institution. Eight days after entering World War I (WWI), the United States, intrigued by the possible missions that UAVs could fulfill, took an interest in the military use of UAVs. These missions were seen as more than just reconnaissance, as attack versions of UAVs were designed and tested, with the goal of eventual operational use. The US Navy awarded a $200,000 contract to Elmer Sperry for him to develop his "Flying Bomb" project. Using an N-9 seaplane and a unique control system based upon gyroscopes, this UAV was to deliver a 1,000-pound bomb to a target 75 miles away with an accuracy of 1.5 miles. Successful testing was sporadic, however, as was further funding. The project was cancelled in 1922, with no operational UAVs delivered.[10]

US Army aviation was also interested in the military use of UAVs for WWI. The ability of a UAV to deliver weapons to a heavily defended target area, without having to worry about harm to the pilot, was of great interest to Army Air Corps personnel. Mr. Charles Kettering of the General Motors Corporation was awarded a contract in January 1918 for 25 Kettering Bugs, a biplane UAV which was designed to deliver 180 pounds of explosives with a 40 mile range. Like Sperry's "Flying Bomb", the Kettering Bug had a poor success rate during testing and was cancelled immediately following the war.[11]

Early UAVs suffered from a technology gap: guidance systems and engines were not sufficiently developed and would continue to hamper successful UAV design. UAVs had a long way to go before they would become effective weapons of war, much less "transformational" weapons.

The Interwar Years and World War II

Manned aviation technology made rapid strides in the period between the World Wars. UAV proponents envisioned several mission areas for UAVs, including reconnaissance and attack roles. The possibility of effectively delivering weapons on a target, with no pilot losses, was an attractive aspect of the UAV, especially in the time of high bomber crew losses over Europe. However, UAV development was not a priority and consequently there were no major leaps in technology. Radio control was introduced in 1924 by the US Army Air Corps

Engineering Division, when they began researching remote control of Curtiss Robin and Stimson Junior aircraft. Their research was finally successful in 1928, when a Curtiss Robin Monoplane became the world's first remotely controlled, weapon-carrying aircraft. However, once again lack of funding and competing manned aircraft requirements led to the cancellation of the program.[12]

UAVs have fulfilled the target drone mission successfully for a long period of aviation history. Drones are used as aerial targets, either for ground forces using anti-aircraft guns or other armed aircraft. This mission can be traced to 1935, when American movie star Reginald Denny founded the Radioplane Company. Denny's family of UAV target drones were highly successful, and the Army Air Corps and Navy purchased nearly 1,000 of his innovative UAVs for anti-aircraft gunnery practice.[13]

After the United States entered WW II, orders for Denny's UAV target drones continued at a tremendous pace. However, despite some success in developing promising military UAV designs in the late 1930s to early 1940s, neither the Army Air Corps nor the Navy considered UAVs to be effective weapon systems. Even the Navy's successful “Project Dog” program, which culminated in the 1941 sinking of a destroyer by a torpedo dropped from a modified single-seat UAV aircraft, did not lead to widespread use in the war.[14]

US Army Air Corps and Navy use of UAVs in WWII was limited to the use of radio-controlled B-17 and B-24 aircraft which were packed with up to 25,000 pounds of explosives. These aircraft, modified under the Project Aphrodite program, were "high-time" aircraft, facing the end of their service life. Launched by a pilot and technician on board the aircraft who then would bail out, the UAV was to be directed toward the target by a trailing escort aircraft. These UAVs were largely ineffective due to their vulnerability to German anti-aircraft defenses and fighter aircraft. In addition, the lack of an effective precision guidance system led to the program's demise.[15] Lieutenant General Jimmy Doolittle's assessment of Project Aphrodite was blunt "...It seems to me that this whole project is put together with bailing wire, chicken guts, and ignorance."[16] Doolittle's criticism notwithstanding, the United States successfully developed some critical UAV technologies during World War II. Several key events in the future, however, were to drive UAV development and operational use to even greater heights.

The Cold War and Vietnam

Following the Second World War, UAV development stagnated once again. Even the impetus of the Korean War did not drive the requirement for UAVs and consequently technological development was not a priority. Modified B-29s were used to launch glide bombs

against North Korean targets. Precision guidance was poor (a common theme throughout early UAV history) and they were not widely used.[17] However, one event, little-heralded at the time, was to become critical to future UAV successes. In 1951, the Teledyne Ryan Firebee, the world's first jet-powered target drone, was introduced. Modified Firebees would go on to serve with distinction in the Vietnam War, as will be seen later.[18]

On 1 May, 1960, a U-2 reconnaissance aircraft piloted by Major Francis Gary Powers was shot down over the Soviet Union. The political fallout from this event drove an immediate requirement for development of a high altitude reconnaissance UAV. Another shoot down of a U.S. reconnaissance aircraft, an RB-47, over the Barents Sea in July 1960, coupled with the shoot down of a U-2 over Cuba in October 1962, also drove a renewed interest in UAV development. Despite encouraging initial studies by Teledyne Ryan into development of a long-range reconnaissance UAV, competing requirements with the manned SR-71 aircraft and satellites combined to once again push the UAV to a low priority.[19] The Powers shoot down was a key event in UAV history because of the focus it put onto the intelligence, surveillance and reconnaissance mission, laying the groundwork for future UAVs such as Predator and Global Hawk.

The political ramifications of the manned aircraft shoot downs early in the Cold War, coupled with the needs of the Vietnam War, drove the U.S. leadership to finally recognize the potential of the UAV. In 1961, the USAF ordered a reconnaissance version of the Ryan Firebee target drone. The Ryan Corporation responded immediately by modifying a Firebee with new navigation and reconnaissance equipment plus increased fuel capacity. The Ryan Model 147 "Lightning Bug" UAV was born, successfully completing testing in 1962. By 1964, a large number of Lightning Bugs were serving with distinction in Southeast Asia.

Between 1964 and 1975, Lightning Bugs flew 3,435 sorties in the Vietnam War. The Bugs proved extremely versatile, flying low and high level reconnaissance, electronic warfare, and leaflet dropping missions. Following another shoot down of a manned aircraft, this time an EC-121 airborne command and control aircraft, the Air Force turned to the UAV to fill the gap. Another version of the Bug was developed to fulfill the airborne electronic intelligence mission; it flew 268 sorties from 1970 to 1973.[20] The Lightning Bug was a milestone UAV that proved its worth in Southeast Asia, and successfully overcame the many technological hurdles experienced in previous UAV development.

Post-Vietnam to the Present

While the United States was evaluating the impact of the UAV in Southeast Asia, the Israelis employed UAVs as a critical weapon system. During the 1973 Yom Kippur War and again during the 1982 Bekaa Valley air battle, the Israelis used UAVs to fool enemy SAM radars by simulating full-size aircraft. Many SAM sites launched their missiles at the UAVs, allowing manned attack aircraft to follow on and directly attack the SAM sites.[21] Israel has continued to employ UAVs as key weapon systems in every conflict since, and has become one of the world's leaders in UAV tactics, techniques and procedures.

In the United States, the early 1970s saw rapid and exciting UAV development. Following the successes of Vietnam, the Israelis innovative use, and successful developmental testing, a whole new set of additional roles for UAVs was envisioned. However, once again an event occurred which, over the long term, undermined UAV development. In 1976, the USAF restructured roles and missions, with the responsibility for UAVs passing from Strategic Air Command (SAC) to Tactical Air Command (TAC). Under TAC, UAV funding suffered a tremendous blow, having to compete for funding with TAC's manned combat aircraft.[22]

The progress made in the 1970s came to an abrupt halt. Under TAC, UAVs were not a priority, and UAV funding suffered greatly having to compete with systems such as the cruise missile force, high speed antiradiation missile and manned strike aircraft. In 1979, over 60 UAVs currently in the US inventory were deactivated and put in long term storage. Five years after their tremendous showing in Vietnam, there were no longer any UAVs in active USAF service.[23] For ten years, from 1979 to 1989, there was no major UAV technological development in the United States.

Finally, in 1989, the DoD established the UAV Joint Project Office, and developed the first "Unmanned Aerial Vehicle Master Plan." This document would evolve into the outstanding "Unmanned Aircraft Systems Roadmap", last published in 2005. Lessons learned from the Israeli UAV experience combined with Operation DESERT STORM in 1991 to once again spur DoD interest in the UAV. During the period from the mid-1990s to the present, the UAV finally stepped out from the shadow of the manned aircraft and gained a place of prominence in the DoD. Before analyzing the general characteristics of UAVs, it is appropriate to examine four key UAV systems currently in use by the DoD.

Figure 1: RQ-2A Pioneer UAV (Photo: US Navy)

Rq-2 Pioneer

A groundbreaking weapon system, the RQ-2 Pioneer was the United States' first tactical battlefield UAV. Developed as a joint venture between Israeli Aircraft Industries and the AAI Corporation, the Pioneer was an improved version of the Israeli "Scout" UAV, used to great effect against Egypt in 1967. First flown in 1985, the Pioneer won a US Navy contract in 1986 for a short range ship-based reconnaissance UAV. The Marine Corps and Army placed orders in 1987 and 1990 respectively for more Pioneers.[24]

The Pioneer is 16 feet long, with a 14 foot wingspan and a gross weight of 450 pounds. It is powered by a 26 horsepower engine driving a pusher propeller. With a cruising altitude of 15,000 feet and a cruising speed of 92 miles per hour, it has an endurance of 5.5 hours. Main sensors include low light level television (LLTV), forward looking infrared (FLIR), chemical and meteorogical monitors, and VHF/UHF radio capability. The Pioneer flies tactical reconnaissance, target acquisition, and battle damage assessment missions. It can be launched by rocket from shipboard or conventional runway, and can be recovered via a capture net on shipboard, or by landing on a conventional runway. Control is via a UHF line of sight data link to a pilot in a ground station.

Pioneers served with distinction in Gulf War I and the Balkans; they currently serve in Operation IRAQI FREEDOM. During Gulf War I, Major General Walter Boomer, Commander of the Marine Expeditionary Force, called the Pioneer his "single most valuable intelligence collector."[25] Thought to be at the end of their service life, Pioneers were ready to be removed from service in 2003. However, developmental problems with its replacement (the RQ-8 "Fire

Scout") have forced the venerable and still quite capable Pioneer to soldier on with the Navy and Marine Corps.[26]

Figure 2: RQ-5A Hunter UAV (Photo: TRW Corporation)

RQ-5/MQ-5 Hunter

Another outstanding workhorse UAV that was developed from an Israeli design, the RQ-5 Hunter's first flight was in 1991. The Hunter went on to win a US Army contract in 1993 for a battlefield surveillance and target acquisition system. Designed by Israeli Aircraft Industries, the Hunter is built by the TRW Corporation (later Northrop Grumman) in the United States.

A twin-boom design (as Pioneer), the Hunter is powered by two 57 horsepower piston engines in a tractor-pusher configuration. Larger than the Pioneer, the Hunter is 23 feet long with a 34 foot wingspan. It has a ceiling of 18,000 feet, cruise speed of 104 miles per hour, and an endurance of up to 18 hours for the MQ-5 version. Hunters were designed to meet the Army's Division and Corps level UAV requirements, and fly medium range reconnaissance and target acquisition missions. On board sensors include a TV/FLIR camera, radio relay systems, and a datalink. It can be preprogrammed to fly autonomous missions, although takeoff and landing must be done manually by a pilot via a datalink and ground station.

After initial successful testing, the Hunter encountered reliability problems in 1995 and the program was terminated in 1996 after the Army contracted for 56 aircraft. They were put into storage, only to be pulled back off the shelf in 1999 for the Balkans conflicts. After they overcame their reliability issues and served with distinction in the Balkans, the Army contracted for 18 additional Hunters in 2004. These new versions were designated MQ-5 and were

modified to carry weapons, including the Viper Strike small guided bomb and brilliant antitank munition. The Hunter is expected to serve until 2009.[27]

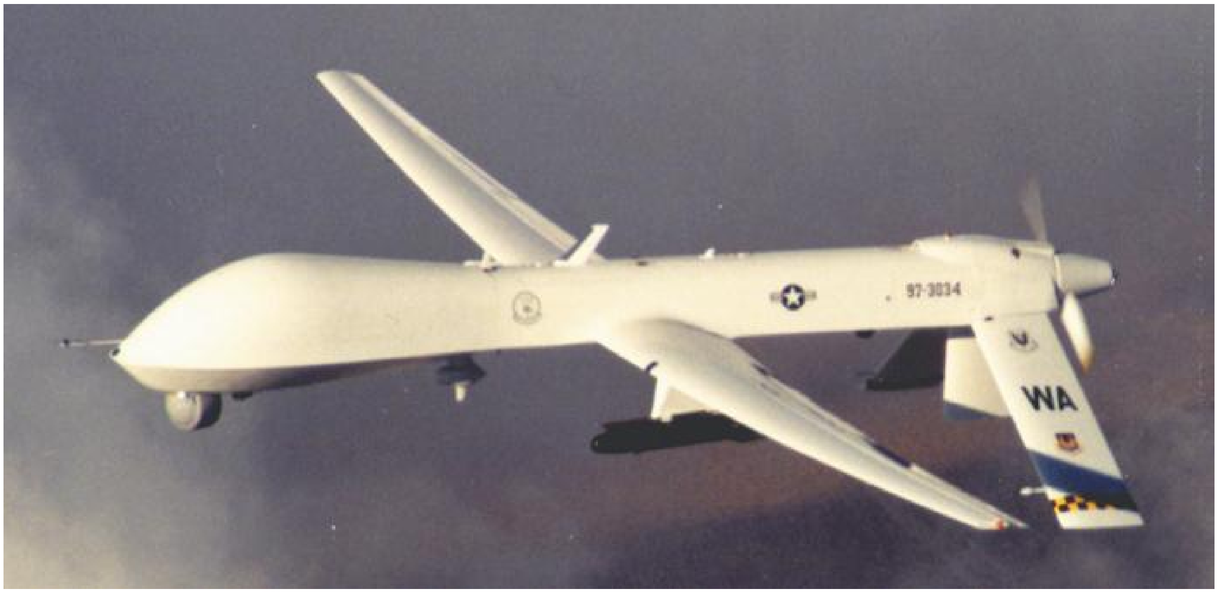

Figure 3: MQ-1B Predator UAV (Photo: General Atomics Corporation)

<u>MQ-1 Predator</u>

No modern UAV has captured the public's attention as much as the MQ-1 Predator. This diminutive workhorse has been involved in US combat operations for over 12 years now. Built by General Atomics Aeronautical Systems Corporation, the Predator evolved from a US Air Force requirement for a medium altitude endurance UAV in 1994. Beginning life as an advanced concept technology demonstrator (ACTD), the Predator was the first ACTD UAV to transition to a full-up Air Force weapon system.[28] In July 1995, Predator ACTD aircraft were deployed to the Balkans, where they performed superbly in the reconnaissance role. After transitioning to an Air Force program in 1997, over 100 Predators had been procured by 2004.

1995 was an historic year for UAVs. In addition to a superb showing in the Balkans Conflict by the Predator, the Air Force formed the 11th Reconnaissance Squadron at Creech Air Force Base, Nevada. This was the service's first-ever UAV squadron. Since then, the Air Force has formed three additional Predator UAV squadrons and one Global Hawk UAV squadron. The Predator has been a consistent requirement by every combatant commander and the Air Force plans to buy 170 Predators by 2010, and 70 more of the MQ-9 Reaper (a larger, more capable version of the Predator).[29]

The Predator is 26 feet long with a 48 foot wingspan. It is powered by a Rotax four-cylinder 115 horsepower engine driving a pusher propeller. With a ceiling of 25,000 feet, the

Predator has a cruising speed of 82 miles per hour, and a combat radius of 500 miles. The most remarkable aspect of the Predator is its endurance, usually in the range of 20 to 24 hours depending on weapon load. In addition, the Predator differs from its Army UAV brethren in the manner of pilot control. After taking off, the Predator is "handed off" from a pilot manning a local line-of-sight ground station via satellite to another pilot sitting in a ground station in the continental United States. The mission is flown this way, via satellite, and then handed off again to a local ground station for landing. In 2001, the Predator was armed for the first time, carrying two Hellfire laser-guided missiles, and the designation was changed from RQ-1 to MQ-1.[30]

With consistent media coverage due to their outstanding service in the global war on terror since 2001, the Predator can be credited with bringing the UAV "into the mainstream" consciousness of the public and the DoD as well. In November 2002, a Predator flying a mission in Yemen fired a missile and destroyed a van carrying senior members of the Al-Qaeda terrorist organization. This marked a turning point in the history of the UAV, as they had finally entered the realm of the combat aircraft.

As previously mentioned, the MQ-9 Reaper is a larger, more capable version of the Predator. Also built by General Atomics, the Reaper was previously known as the Predator B. The Reaper is 36 feet long with a 66 foot wingspan, and is powered by a Honeywell TPE-331 turboprop engine developing 900 horsepower. The Reaper's weapon load is ten times that of the Predator, capable of carrying up to 3,000 pounds on six underwing hardpoints. With the same endurance as Predator, the Air Force has categorized the Reaper as a "hunter-killer" aircraft -- the attack mission takes precedence over the reconnaissance mission. The Air Force formed the 42nd Attack Squadron at Creech Air Force Base in 2006, the first Reaper unit, and plans to buy up to 70 MQ-9s by 2009.[31]

Figure 4: RQ-4A Global Hawk UAV (Photo: USAF)

RQ-4 Global Hawk

No less remarkable than the Predator, but with a somewhat more difficult development path, the Global Hawk was initiated in 1995 to fulfill an Air Force requirement for a strategic reconnaissance high-altitude UAV. After completing its first flight in 1998 as an ACTD aircraft, the Global Hawk was pressed into war service immediately, much like Predator. After performing superbly while supporting both Operations IRAQI FREEDOM and ENDURING FREEDOM, the Global Hawk transitioned from an ACTD to a normal acquisition program in 2001. The Air Force initially ordered 63 Global Hawks, but cost overruns have forced the purchase to be scaled back to 51 total aircraft.[32]

An engineering marvel, the Global Hawk is the largest military UAV in service. It is 47 feet long with a massive 131 foot wingspan. The power plant is a 7,600-pound-thrust Rolls Royce AE-3007 turbofan engine. Sensor payload is 3,000 pounds and includes electro-optical, infra-red, synthetic aperture radar, and signals intelligence systems. The Global Hawk orbits at 65,000 feet, with a cruising speed of 350 miles per hour, and a mission radius of 6,000 miles. It flies strategic reconnaissance missions, and can survey large geographic areas on one mission, with an endurance of 28 hours.[33]

The Global Hawk encountered cost overruns and program delays, due to the integration of many new and advanced technologies. Originally projected to cost $85 million per aircraft, the program cost has soared to $123 million per aircraft currently. The Global Hawk is planned to eventually replace the venerable U-2 manned strategic reconnaissance aircraft, if technological hurdles can be overcome and it is able to perform all of the U-2's current missions. To gain synergy, the Global Hawk is based alongside the U-2 at Beale Air Force Base, California.

Analysis: Assets of the UAV

The cost of UAVs relative to manned aircraft is a topic that has been the subject of debate throughout their history. It cannot be argued that the unit cost of UAVs is less than manned aircraft. For example, the Predator unit cost is $4.5 million and the Reaper is $11 million. This compares favorably with the unit costs of an F-16 and F-15E, at $18 million and $31 million respectively.[34] However, advanced technology sensor costs have driven up UAV costs, as in the Global Hawk program, with a unit cost of $123 million. In addition, UAVs have a higher accident rate than comparable manned aircraft, and must be replaced more often, driving up overall cost. A 2004 study by the Defense Science Board, Office of the Secretary of Defense, found that the rising overall program cost of UAVs was "potentially limiting the development,

acquisition, and use of UAVs..."[35] The study went on to recommend that future combat UAV program cost should be capped to a percentage of a comparable manned aircraft.

Persistency, a product of the incredible endurance of most of the current DoD UAV platforms, is a tremendous attribute. With no onboard pilot, the UAV eliminates the limitations of aircrew fatigue. Compared to manned aircraft, the combat UAV can loiter over a target area orders of magnitude longer. A fully-armed F-16 will most probably be in the target area for 30 minutes before having to air refuel. A Reaper UAV, with a comparable weapon load, could orbit the area for 18-20 hours.[36] This attribute has made the UAV a critical weapon in the current asymmetric global war on terror, able to loiter over an area and observe continuously for many hours. In addition, UAV persistence is transforming the way the Air Force conducts mission planning. Near-continuous surveillance of an area, when UAVs are part of a larger system of manned aircraft and space systems, is no longer a fantasy.

Modern UAVs do not operate independently but are part of the larger "net-centric" modern battlefield. This concept of an integrated battlespace, fusing command and control, intelligence, and battle management systems, is a force multiplier. The DoD's goal is to reach a stage whereby intelligence data, targeting information, and key command and control communications can be passed instantaneously between all weapon systems and units on the battlefield. With their persistence and advanced sensors, modern UAVs are a critical element of the "net-centric" battlefield.[37]

In addition to persistence, another inherent quality of the UAV is versatility. Historical UAV development was marked by imagination and innovation as pioneers envisioned UAVs performing a wide array of missions. The vision of these UAV pioneers is finally becoming reality, as modern UAVs have undertaken missions across the spectrum and are poised to expand into even more areas. Combatant commanders now have UAV systems that can perform ISR, target cueing, weather data collection, and battle-damage assessment. Radio relay is another mission area that is ready to be performed by UAVs. With the arming of the Predator and the fielding of the Reaper, UAVs have become combat aircraft by performing close air support and air interdiction missions. In addition to strictly military missions, UAVs are flying border patrol, anti-drug, maritime vessel identification, and search and rescue missions.[38]

Over the past ten years, the UAV has finally been accepted by the DoD as a viable weapon system. Major strategic-level functions and offices have declared the UAV to be a vital, even transformational, component in the fight against global terrorism. A 2004 Defense Science Board Task Force concluded "...it is time for DoD and the Services to move forward and make UAVs...an integral part of the force structure."[39] The 2005 US Air Force UAV Strategic Vision

declared "Unmanned aircraft are a critical piece of ongoing Air Force transformation."[40] The Secretary of Defense's 2005 UAV Roadmap stated "As the global war on terrorism...enters its fourth year, the contributions of unmanned aircraft in sorties, hours, and expanded roles continue to increase."[41] This tremendous interest in the UAV by strategic leadership throughout the DoD has led to a dramatic increase in the total budget for UAVs. From 1990 to 1999, the DoD spent $3 billion on UAV development, procurement and operations. This is projected to grow to $15 billion for the period 2000-2009, a five-fold increase. The current DoD UAV inventory of 250 aircraft is on track to grow to 675 by 2010 and 1,400 by 2015.[42] In the Global War on Terror, UAVs are quickly moving from a secondary role to one of prominence.

One obstacle that the UAV has only recently overcome is the perceived manned aircraft institutional bias. The "white scarf syndrome," as described by Carl Builder in his book *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the US Air Force,* refers to the Air Force's institutional preference for manned aircraft versus alternative weapon systems, such as UAVs.[43] While this perception was most probably closer to reality in the earlier days of aviation, it is not clear if it was as large a factor in recent history. The lull in UAV development from the mid-1970s to the mid-1990s was attributable mostly to a general skepticism of UAV effectiveness, rather than strictly the "white scarf syndrome."[44] But the Predator's outstanding performance in Kosovo seemed to be the turning point for the UAV in terms of acceptance by Air Force leadership. In 1999, General Michael Ryan, then Chief of Staff of the Air Force, attributed UAV acceptance to the Predator's targeting, imagery transmission capabilities and relatively low cost; he stated: "It's where money came together with capability."[45] However, the explosion of UAV development and procurement over the past ten years is a good indication that the UAV has finally overcome whatever bias had been erected in its path.

Nearly all current UAV systems operate with a pilot in control of the aircraft, via an electronic datalink. The next step in development is a UAV capable of truly autonomous operation. The Joint Unmanned Combat Aircraft System (J/UCAS) program was a dual Air Force-Navy effort to develop a stealthy, high-subsonic jet UAV, which was to perform the electronic attack and penetrating strike missions. However, DoD senior leadership, in the 2006 Quadrennial Defense Review (QDR), canceled the current J/UCAS program and directed the Air Force to take the technologies developed and apply them to a new long-range strike platform, to be fielded by 2018.[46] The Navy may continue the current program to develop a carrier-based, stealthy attack UAV. The J/UCAS has successfully tested several new UAV capabilities, including semi-autonomous operation, multi-UAV control by a single operator,

formation flight, and multi-UAV attack planning. Autonomous aerial refueling was to be another key capability of the J/UCAS and was only recently tested. In September 2006, a modified F/A-18 aircraft was flown as a UAV, and successfully refueled in flight from a KC-135 tanker, a first in UAV history.[47] Clearly the UAV is in the middle of an ongoing phase of tremendous technological advancement.

Fully autonomous operation by an armed UAV raises interesting questions pertaining to the law of armed conflict (LOAC). Under LOAC, only a combatant, as defined by The Hague and the 3rd Geneva Convention, may employ a weapon in combat. A fully autonomous combat UAV would not be able to fire weapons according to these criteria.[48] Either future UAV designs must include a human in the weapon authorization loop, or current LOAC criteria may need to be reviewed in light of the modern net-centric battlefield. Recently, contractor pilots flying the Predator during Operation IRAQI FREEDOM were prevented from employing weapons under LOAC, and instead were relegated to performing takeoffs and landings. Weapon release was clearly defined as solely the duty of uniformed military personnel.[49] The unique nature of the UAV raises doctrinal, operational, organizational, and legal questions that users will need to resolve.

Conclusion

> We have just won a war with a lot of heroes flying around in planes. The next war may be fought with airplanes with no men in them at all. It certainly will be fought with planes so far superior to those we have now that there will be no basis for comparison. Take everything you've learned about aviation in war and throw it out of the window and let's go to work on tomorrow's aviation. It will be different from anything the world has ever seen.[50]
>
> —General Henry H. "Hap" Arnold (1945)

General Arnold's prophetic statement about the future of aviation, made after the Second World War, has equal power today. The UAVs long history of rapid technological development followed by periods of stagnation is finally over. By becoming a critical asset in today's asymmetric spectrum of warfare, the UAV has overcome the manned aircraft institutional bias.

There is a growing consensus among DoD leadership that the UAV is indeed transformational. The 2004 Defense Science Board Task Force on Unmanned Aerial Vehicles stated "The success of UAVs in recent conflicts represents a historic opportunity to exploit the transformational capabilities inherent in UAVs."[51] The 2005 Secretary of Defense Unmanned Aircraft Systems Roadmap concurs, stating "[Unmanned aircraft]...are changing the conduct of military operations in the global war on terror."[52] Major General James D. Thurman, Director of

the Army Aviation Task Force, states "...[UAVs] represent tremendous potential and almost limitless possibilities for the future. Feedback from all echelons of command - platoons to combat commanders - tells us that UAVs are here to stay."[53]

As defined previously, an RMA consists of three core concepts. First, a radical new technology or strategy is adopted. Second, this new technology or strategy drives major doctrinal or organizational changes. Finally, this radically alters the nature of warfare. While not a new technology, the UAV was only recently embraced as a viable weapon system, so it can be argued effective UAV technology is indeed radically new. The DoD has made the UAV one of its top priorities in recent defense budgets and UAV funding is projected to exceed $15 billion during the decade of 2000-2009. The unique combat employment of UAVs, with the pilot removed from the aircraft and sitting in a control station thousands of miles away, is driving doctrinal changes. The UAV has begun to alter the nature of warfare, and will almost certainly continue to do so.

The first 100 years of the UAV's 110-year history was marked by evolutionary development. Slow, steady progress was made on many technological improvements, and the major hurdles of reliable propulsion and control systems were finally overcome. Over the last ten years, however, UAVs have truly come into their own, and pace of change can be considered revolutionary. Reliable, effective UAV platforms were finally developed, and they have transformed the nature of air warfare.

Endnotes

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